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## ABSTRACT

This document describes a general introductory course in applied science intended for students of various interests and abilities. The course is designed to provide high school students with a basic understanding of the space age with an emphasis on model rocketry. Included is an outline of the subject matter to be covered in units on: (1) constructing and launching model rockets; (2) the laws of motion and energy; (3) rocket aerodynamics and propulsion systems; (4) recovery techniques; (5) altitude tracking; (6) the earth and our solar system; (7) the history of space flight; (8) future space projects; (9) aerospace industry related careers; (10) projects and reports; (11) advanced model rocket techniques; and (12) individual projects and demonstrations. For each unit a cross-reference of proficiency requirements, key vocabulary words, and useful printed and audio-visual materials is provided. The course description stresses the use of various indoor and outdoor hands-on activities and laboratory experiences. The appendix contains the model rocketry safety code of the National Association of Rocketry and the Hobby Industry of America. (TW)

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## COURSE GUIDE:

MODEL ROCKETRY  
in the  
High School  
(grades 9-12)

by

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Lancaster High School  
Lancaster, Ohio

Fall 1985

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TO THE EDUCATIONAL RESOURCES  
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Roger Grossenbacher received his Master's degree in Astronomy at Case Institute of Technology in 1967. He has been director of Peters Planetarium since 1971. He also teaches physics and astronomy at Lancaster High School, Lancaster, OH. He also teaches astronomy at the Ohio University Lancaster branch. He has worked at observatories in Ohio, Connecticut, and Hawaii. While at Wesleyan University he taught a course on UFOs.

His published scientific papers include ones on measurements of stars' distances and masses. Several of his articles and program scripts have appeared in planetarium journals.

Roger is a member of the National Education Association, International Planetarium Society, Great Lakes Planetarium Association, and the Astronomical Society of the Pacific.

Model rocketry is used in his physics classes. He attended the graduate workshop on model rocketry offered by Colorado State University in 1984.

## MODEL ROCKETRY AND AEROSPACE SCIENCE

### COURSE DESCRIPTION

1 CREDIT - 5 LAB LENGTH (60 MINUTE) PERIODS PER WEEK, ONE YEAR, GRADE 9

This is a general introductory course in applied science intended for students of various interests and academic abilities. The course will provide students with a basic understanding of the development of the space age with emphasis on model rocketry.

Students will be exposed to a wide variety of topics, such as: History of space exploration; design, propulsion, and aerodynamics of rockets; altitude tracking; the Solar System; and life on other planets. The course involves equal emphasis of laboratory activities and lecture/discussion. Various indoor and outdoor hands-on activities will be used. The students will design, build, paint, test, and fly several different model rockets. When available, guest speakers representing various occupations that deal with aerospace industries will be incorporated into the course.

With the approval of the instructor, each student will investigate individual areas of interest related to rocketry or space science and complete two in-depth course projects. This course is not to be taken in lieu of biology, chemistry, or physics by a student who will attend college.

Prerequisites: None

#### PHILOSOPHY OF THE COURSE

1. This course follows the trend toward offering science courses that are activity oriented. It is based on the idea that all students need to be scientifically and technologically literate. The students use the subject matter studied.
2. The course is designed to meet the science needs and interests of those students who are not necessarily college bound. Students of various abilities and interests will be encouraged to successfully work together in new situations.
3. The amount of scientific knowledge increases each day. There is a need for an interdisciplinary science course that covers those areas of knowledge and skills that other science courses are unable to cover adequately.
4. This course is intended to enable students to gain a greater appreciation of the laws of physics and of our space environment. Students should gain a better understanding of the growing influence of space exploration on their lives.
5. Finally, it is the intention of this course to enable students to have a greater understanding of various occupations related to rocketry and aerospace science.

MODEL ROCKETRY AND AEROSPACE SCIENCE

SUBJECT MATTER OUTLINE

- Unit I. Constructing and Launching Model Rockets
  - A. Basic parts of a model rocket and their functions
  - B. Model Rocketry Safety Code
  - C. Construction and finishing techniques
  - D. Build model rocket using standard engine power
    - 1. Use streamer recovery for simplicity
    - 2. Test for stability
  - E. Organize launch teams
    - 1. Duties of each member of team
  - F. Launch and recover rockets
- Unit II. The Laws of Motion and Energy
  - A. Define speed and acceleration
  - B. Newton's first law (inertia)
  - C. Newton's second law (momentum change)
    - 1. Mass compared to weight
    - 2. Momentum and impulse
  - D. Newton's third law (action-reaction)
  - E. Define work, energy (kinetic, potential)
  - F. Define power
- Unit III. Rocket Aerodynamics and Propulsion Systems
  - A. Lift, weight, thrust, and drag forces
    - 1. Air pressure and Bernoulli's principle
    - 2. Factors affecting drag (frontal area, shape, surface finish, density of atmosphere)

- B. Center of gravity and center of pressure
- C. Roll, pitch, and yaw motions
  - 1. Methods to achieve stable flight (control surfaces, gimbals, spin, inertial guidance, thrusters)
- D. Engine parts and terminology
  - 1. Liquid fuels and oxidizers
  - 2. Solid fuels, engine construction, and burning patterns
  - 3. Model rocket engine code rating system
  - 4. Electrical circuits used in remote engine ignition (Ohm's law, parallel and series circuits, switches, electrical power supplies)

Unit IV. Recovery Techniques

- A. Aerodynamics of gliding flight
- B. Drag
- C. Recovery techniques (streamer, parachute, tumble, glide)

Unit V. Altitude Tracking

- A. Elementary trigonometry
  - 1. Similar triangles
  - 2. Sine, cosine, and tangent ratios
- B. Theory of 1- and 2- station altitude tracking.
  - 1. Methods for establishing a known baseline
  - 2. Devices for measuring altitude and azimuth angles
- C. Practice using tracking methods
  - 1. Determining height of stationary tall object (flagpole)
  - 2. Tracking actual model rockets in flight

Unit VI. The Earth and Our Solar System

- A. Earth's properties
  - 1. Mass, density, composition

2. Interior features and temperatures
3. Surface features and continental drift
4. Atmospheric layers, content, temperature, pressure, and circulation
5. Radiation belts and magnetosphere

B. The Solar System

1. The sun as a star
2. Distances of planets from the sun
3. Characteristics of inner and outer planets and their moons.
4. Asteroids, comets, and meteors
5. Theories of origin
6. Reasons for investigating our Solar System with both Earth-bound instruments and probes launched into space

C. Life on Other Planets

1. Characteristics of known living things
2. Energy and materials requirements of living things
3. Most likely places for life in our Solar System
4. The search for planets beyond our Solar System

Unit VII. History of Space Flight

- A. Ancient Chinese rockets and pre-20th century rockets
- B. Goddard and the development of modern rocketry
- C. World War II weapons (V1, V2, Me 163, OKA-11 bomb)
- D. Multistage rockets and their advantages
- E. Rocket research aircraft and high speed flight in the atmosphere (X-1, X15, SR71, Concorde)
- F. Sputnik and later artificial satellites
  1. The law of gravity and Kepler's laws

2. Orbital velocity and elliptical versus circular orbits
  3. Period of orbit depends on size of orbit
  4. Radio telemetry and tracking techniques
  5. Recovery of payloads from orbit
  6. Synchronous satellites and their uses in weather, communications, and espionage
- G. Unmanned lunar and planetary probes
1. Achieving escape velocity and transfer orbits
  2. Russian probes (Lunik, Zond, Lunikhod, Venera)
  3. U.S. probes (Ranger, Orbiter, Surveyor, Mariner, Viking, Pioneer, Voyager)
  4. Conversion of digital radio signals into TV pictures
- H. Hazards of manned space travel
1. Acceleration and weightlessness
  2. Noise and vibration
  3. Radiation
  4. Meteoroids
  5. Thermal effects
  6. Vacuum
- I. Basic elements of living in space
1. Pressurized, shielded enclosure
  2. Electrical power
  3. Environmental control (atmosphere, heat)
  4. Water and food
  5. Exercise and personal hygiene
  6. Space suit design for Extra Vehicular Activity

- J. Space navigation and orbital maneuvers
  - 1. Sun and star tracking
  - 2. Matching orbit planes and velocities
- K. Past manned space exploration
  - 1. Russia's program (Vostok, Voskhod, Soyuz)
  - 2. U.S. program (Mercury, Gemini, Apollo, Skylab, Apollo-Soyuz)
    - a. Objectives (launch, orbit, reentry, and safe recovery; rendezvous and docking; moon landing; long term effects on the human body; international cooperation and rescue capability)
    - b. Spacecraft and launch vehicle designs
    - c. Flight profiles and mission chronology
    - d. Summary of accomplishments
- L. Present Space Activities
  - 1. U.S. Shuttle
    - a. Re-useability and economy
    - b. Industrial and scientific uses (Spacelab)
    - c. Military uses
  - 2. Russian Salyut space station
    - a. Long-term space habitation
    - b. Re-supply by unmanned ships
  - 3. French Arienne launch vehicle
  - 4. Voyager and Galileo probes to outer planets and asteroids
  - 5. International comet probes (ICE, VeGa, Giotto, Planet A, MS-T5)
- M. Benefits of space exploration to mankind
  - 1. Faster, smaller calculators and computers
  - 2. Satellite TV communications

3. Medical monitoring equipment
4. Agricultural and geological monitoring
5. Other spinoffs (commercial products and processes)
6. Indirect benefits (perspective on our place in the universe)

#### Unit VIII. Future Space Projects

- A. Permanent earth-orbiting space stations
  1. Economic benefits in specialty manufacturing
  2. Medical and industrial research and development
  3. Space telescopes
- B. Space colonies and solar energy satellites
  1. Costs and advantages
  2. Worldwide power needs
  3. Lunar support mining colonies
  4. Possible self-sufficiency
- C. New propulsion and lifting designs
  1. Solar sails
  2. Mass drivers
  3. Space cable-elevator or skyhook
  4. Nuclear engines
  5. Interstellar ram jets
  6. Matter-antimatter drives
- D. Manned flights to the Moon, Mars, the asteroids, and other bodies in our Solar System.
  1. Scientific goals
  2. Industrial use of raw materials
  3. Special problems for crews

E. Manned flights beyond our Solar System

1. Ways to meet enormous propulsion needs
2. Crew hibernation
3. Flight near the speed of light
4. Possible destinations
5. Purposes

Unit IX. Aerospace Industry Related Careers

A. Branches of aerospace industry

1. Private and commercial aircraft manufacturing
2. Military aircraft manufacturing
3. Rocket manufacture
4. Airports and service facilities
5. NASA facilities and functions
  - a. Aeronautical
  - b. Space

B. Aerospace Careers

1. Professional opportunities in the physical sciences, engineering, mathematics, space medicine, and computer science
2. Semi-professional opportunities for technicians, managers, and related occupations
3. Military aviation opportunities
4. Astronaut training and selection
5. Necessary educational background for various careers
6. Universities and other institutions offering aerospace training

Unit X. Projects and Reports

A. Indoor paper airplane contest events

1. Accuracy (hit a 1 meter target from a 5 m distance)

2. Maneuverability (hit the same target from 5 m after going around a pylon)
  3. Maximum distance
  4. Maximum duration
- B. Students' choice of group projects which may include some of the following:
1. Wind-tunnel construction and testing
  2. Rocket engine time-thrust tester
  3. Building transit telescopes for tracking model rocket flights and other uses
  4. Designing future spacecraft and planning missions for them
  5. Computer-simulated flight to Moon or Mars
  6. Building graphic device for 2-station tracking solutions
  7. Studying the effects of streamlining rocket parts
  8. Analyzing the effects of surface finish on rocket performance
  9. Evaluating the effects of parachute size and total model rocket weight on descent rate
  10. Building radio telemetry transmitter and receiver for model rockets
  11. Building movie camera for launch aboard a model rocket
  12. Building a multiple pad launch system
  13. Assembling an antenna to receive signals from satellites
- C. Student demonstrations and oral reports on project results

#### Unit XI. Advanced Model Rocket Techniques

- A. Scratch-built models
1. Construction techniques necessary to build safe model rockets from parts or "from scratch"
  2. Using everyday household materials to build safe model rockets

- 3. Stability tests
- 4. Initial flight tests
- B. Scale models
  - 1. Techniques of scaling
  - 2. Construction and detailing methods
  - 3. Finishing techniques
  - 4. Addition of extra fins for stability
- C. Multi-stage model rockets
  - 1. Necessity for string test on each flight configuration
  - 2. Selection of engines
- D. Engine clustering techniques
  - 1. Evaluation of mission to determine necessity for cluster of engines
  - 2. Feasible arrangements of engines
  - 3. Power and wiring circuits needed for simultaneous ignition
- E. Payload-carrying rockets
  - 1. Weight limits
  - 2. Design of payloads and payload compartments
  - 3. Restrictions on live payloads
- F. Aerial photography
  - 1. Camera design and construction
  - 2. Optimizing launches for best pictures
  - 3. Interpretation of photos
    - a. Information about area photographed
    - b. Determination of altitude at which picture was taken

G. Boost gliders

1. Front and rear engine designs
2. Piggy-back launch on a separate rocket
3. Unique gliders

H. Accurate methods of determining peak rocket altitudes (apogees)

1. Using 2 or more transit-type sighting devices
2. Using surveyor's transit

I. Altitude prediction methods

1. Drag Coefficients
2. Use of prediction charts
3. Use of slide-rule type altitude prediction devices

Unit XII. Individual Projects and Demonstrations

Each project requires significant accumulation of knowledge, solution of practical engineering problems, collection and analysis of data, and conclusion-reaching. Students will select from such choices as the following:

A. Model rocket - building and flying

1. Scale model
2. Scratch-designed and built model rocket
3. Student-designed model rocket using commercially available parts
4. Multistage
5. Cluster-powered
6. Payload carrier
7. Boost glider
8. Rocket-borne camera
9. Rocket with telemetry (as recording barograph or thermograph)
10. Illuminated nose cone for night launch

B. Computer-related activities

1. Countdown monitoring
2. Computation of power developed by engine-rocket combination
3. Altitude prediction
4. Altitude tracking computation
5. Computer - aided design of rockets

C. Competition events

1. Greatest altitude
2. Combination payload and altitude
3. Best prediction of altitude
4. Longest glider duration
5. Egg payload launch (egg loft)
6. Egg nose cone
7. Scale model appearance

SUBJECT PROFICIENCY REQUIREMENTS, VOCABULARY, AND  
USEFUL PRINTED AND AUDIO-VISUAL MATERIALS

Every student must complete the following to receive credit for this course:

- A) Two major projects involving some aspect of rocketry or aerospace science, one a group project and the other an individual effort.
- B) Grades of 60% or higher on exams over each of the nine units other than projects. In addition to the above proficiency, the student must demonstrate mastery of 60% of the following. Each proficiency should be read as (The student should be able to....)

For vocabulary terms, the student should be able to spell and use each word correctly in a sentence or match it with its definition with 60% accuracy.

I. Constructing and Launching Model Rockets

- 1-1 Construct a standard engine model and test its stability.
- 1-2 Identify the parts of a model rocket and explain purpose of each.
- 1-3 List the 14 items of the Model Rocketry Safety Code.
- 1-4 Launch and recover his rocket safely.
- 1-5 Carry out his duties as a member of his launch and recovery team.

Vocabulary: Fin, body, nose cone, engine mount, launch lug, shock cord, recovery device, stability, center of gravity, tracking charge, ejection charge, center of pressure, lift, drag, model rocket, model rocket engine, electrical ignition system, aerodynamics, model rocket flight profile, boost phase, recovery phase, ignition, countdown, propellant.

- Materials:
- 1) Model Rocket Technical Manual by W. Simon (Estes)
  - 2) Estes Flying Model Rocket Catalog (current year)
  - 3) Teacher's Manual to "Space Age Technology" by S. Hajek and R. Schuette (Estes)
  - 4) (Movie) Model Rocketry: The Last Frontier (free loan from Modern Talking Picture Service, 5000 Park Street N, St. Petersburg, FL 33709)

## II. The Laws of Motion and Energy

- 2-1 Compute the speed and acceleration of a cart using a tick timer and ruler.
- 2-2 Compute the momentum and kinetic energy of a moving body.
- 2-3 Compute the gravitational potential energy of a rocket at the top of its trajectory.
- 2-4 Compute your own power output when climbing stairs at top speed.
- 2-5 Match metric units of mass, weight, energy, and power with their respective physical quantities.

Vocabulary: Speed, acceleration, inertia, mass, weight, momentum, impulse, work, energy, kinetic, potential, joule, watt.

- Materials:
- 1) The Laws of Motion and Model Rocketry by R. Cannon (Estes)
  - 2) A Demonstration Handbook for Physics by G. Frier and F. Anderson, American Association of Physics Teachers, Graduate Physics Bldg., SUNY, Stony Brook, NY 11794.
  - 3) Modern Physics by Williams, Trinklein, and Metcalfe, Holt-Rinehart.

## III. Rocket Aerodynamics and Propulsion Systems

- 3-1 Locate the centers of gravity and pressure of a model rocket.
- 3-2 Assemble an electrical ignition system for model rocket engines and burn an igniter with it.
- 3-3 Describe the meaning of the three parts of the code on a model rocket engine.
- 3-4 List three factors affecting drag.
- 3-5 Distinguish between roll, pitch, and yaw.

Vocabulary: Lift, thrust, drag, roll, pitch, yaw, tip edge, root edge, leading edge, trailing edge, gimbal, oxidizer, specific impulse, exhaust velocity, mouth, throat, bell, combustion chamber, hypergolic, series and parallel circuits, Ohm's law.

- Materials:
- 1) TR-8 Model Rocketry Study Guide (Estes)
  - 2) TN-1 Model Rocket Engines (Estes)
  - 3) Learning Guide for Model Rocket Launch Systems,  
by R. Cannon (Estes)

#### IV. Recovery Techniques

4-1 Launch a model rocket and recover it safely via parachute.

4-2 Layout a measured baseline and determine the altitude of a model rocket at its apex.

Vocabulary: Drag, aerodynamic braking, recovery system, ejection charge, parachute, streamer, glide, tumble, break-apart, tumble, helicopter, pop-pod, touchdown.

- Materials:
- 1) Model Rocketry Technical Manual (Estes)
  - 2) Countdown: Mathematics and Model Rocketry by  
W. Schall (Estes)
  - 3) TR-3 Altitude Tracking (Estes)
  - 4) TN-6 Recovery Techniques (Estes)

#### V. Altitude Tracking

5-1 Use an astrolabe of his own construction to measure the height of a flagpole.

Vocabulary: Trigonometry, similar triangles, hypoteneuse, opposite and adjacent sides, tangent, pi, circumference, radius, diameter, baseline, astrobabe, trajectory, projectile.

- Materials:
- 1) Model Rocketry Technical Manual (Estes)
  - 2) Countdown: Mathematics and Model Rocketry by  
W. Schall (Estes)
  - 3) TR-3 Altitude Tracking (Estes)
  - 4) TN-5 Elementary Mathematics and Model Rocketry

#### VI. The Earth and Solar System

6-1 Identify five major differences between giant and terrestrial planets.

6-2 Identify slides of the planets and their more distinctive moons.

- 6-3 List the planets in order of their distance from the sun.
- 6-4 Distinguish between comets, meteors, and asteroids.
- 6-5 Describe how studies of other planets can help us better understand the earth's geology and weather.
- 6-6 Describe the characteristics of known living things.
- 6-7 Describe the environmental needs of known living things.

Vocabulary: Crust, mantle, core, troposphere, stratosphere, mesosphere, ionosphere, exosphere, thermonuclear fusion, hydrogen, helium, carbon dioxide, oxygen, nitrogen, ammonia, methane, astronomical unit, Bode's law, density, rotation, revolution, environment, food, shelter, predators, herbivore, carnivore, omnivore, ecology.

- Materials: 1) National Geographic magazine, Jan. 1985 "The Planets"
- 2) National Geographic Society filmstrip series: "Inner Planets", "Outer Planets", "Comets, Asteroids, and Meteors", "The Sun"
  - 3) NASA movies: "The Moon, an Emerging Planet", "Mercury, Exploration of a Planet", "Planet Mars"
  - 4) NASA Facts, NF 134/8-82, "Our Planets at a Glance"

## VII. History of Spaceflight

- 7-1 Locate 10 space milestones on a timeline from 1926 to 1990.
- 7-2 Identify slides of 10 rockets and spacecraft.
- 7-3 Construct and interpret a hypothetical two-dimensional space scene from digital telemetry data.
- 7-4 Describe 5 important things learned by sending men to the moon.
- 7-5 Explain the main motives for sending men to the moon.
- 7-6 Draw an elliptical orbit and label the foci, apogee, perigee, and major axis.
- 7-7 List three practical uses of synchronous earth satellites.
- 7-8 List provisions that must be made to carry men safely into space.

Vocabulary: Satellite, ellipse, focus, major axis, apogee, perigee, orbital speed, escape velocity, telemetry, bit rate, pixel, fuel cell, recycling, rendezvous, EVA, staging, synchronous.

- Materials: 1) Man's Conquest of Space by W. Shelton

- 2) Frontiers of Science, National Geographic Society, Chapter 3
- 3) Red Star in Orbit, by J. Oberg
- 4) Space Shuttle Operator's Manual by Joels and Kennedy.
- 5) Space Science Involvement (Oscar amateur radio satellites), American Radio Relay League, Newington, CT 06111
- 7) Movie: The Right Stuff
- 8) NASA movies: "Zero g", "Living in Space", "Space Navigation", "Apollo-17", "4 RMS-Earth View" (Skylab), "Mission of Apollo-Soyuz", Space Shuttle post-flight press conferences (STS-7, 41-C, and others)

#### VIII. Future Space Projects

- 8-1 List 5 economic benefits of space exploration.
- 8-2 Describe 3 potential new space propulsion systems.
- 8-3 List 3 space exploration goals that have yet to be accomplished.

Vocabulary: Lagrange points, microwaves, mass driver, relativity, time dilation, ram jet, anti-matter, radiation pressure, solar wind.

- Materials:
- 1) The High Frontier by G. O'Neill
  - 2) Colonies in Space by F. Heppenheimer
  - 3) Mission to Mars by J. Oberg
  - 4) 1984: Spring by A.C. Clark

#### IX. Aerospace Industry and Related Careers

- 9-1 Obtain a catalog and sample curriculum from an accredited school of aerospace education.
- 9-2 Write a report on a visit to a local planetarium, military air base, airport, NASA facility, or aerospace manufacturer.

- Materials:
- 1) AviationSpace magazine, Aerospace Education Association, 1010 Association Drive, Reston, VA 22091
  - 2) Aerospace magazine, Aerospace Industries Association of America, 1725 De Sales St. NW, Washington, DC 20036

- 3) Publications of the National Aerospace Education Council, 1025 Connecticut Ave. NW, Washington DC 20036

X. Projects and Reports

- 10-1 Design and fly a paper airplane in 4 different performance events.
- 10-2 Work with one or two other students on a project to study one aspect of rocketry or space science in detail.
- 10-3 Present a written and oral report on his project results.

- Materials:
- 1) Projects in Model Rocketry by R. Cannon (Estes)
  - 2) "Is Your Hobby Physics?" by H. Taitt, Physic Teacher, March 1975
  - 3) "Project Parsec Goes to Mars" by R. Hillenbrand and M. Ryan, Sky & Telescope, December 1977
  - 4) TR-5 Building a Wind Tunnel (Estes)
  - 5) TN-3 Is That Parachute Too Big? (Estes)
  - 6) Countdown: Mathematics and Model Rocketry (Estes)
  - 7) The Astronomy Disk (computer software) by S. Simon, Astronomical Society of the Pacific, 1290 24th Ave., San Francisco, CA 94122

XI. Advanced Model Rocket Techniques

- 11-1 Use of a transit instrument to measure the altitude and azimuth of a rocket in its apogee.
- 11-2 Compute the maximum height of a model rocket from two simultaneous transit observations.
- 11-3 Predict the peak altitude of a given rocket and engine combination using altitude prediction charts.
- 11-4 Determine the scale of a rocket aerial photo or satellite earth photo.
- 11-5 Locate your city or nearby large natural or man-made feature on a Landsat photo of your state.
- 11-6 Locate the tallest structure on a stereopair of aerial photos.
- 11-7 Draw a circuit diagram for wiring igniters on a cluster rocket's engines.
- 11-8 Describe the advantages of using multi-stage rockets.

Vocabulary: Transit, drag form factor, ballistic coefficient, drag coefficient, burnout velocity, ground truth verification, stereo-pair, infrared.

- Materials:
- 1) TR-2 Multistaging (Estes)
  - 2) TR-4 Rear-Engine Boost Gliders (Estes)
  - 3) TR-6 Cluster Techniques (Estes)
  - 4) TR-10 Altitude Prediction Charts (Estes)
  - 5) TR-7 Front-Engine Boost Gliders (Estes)
  - 6) TN-4 Payload Launching (Estes)
  - 7) NASA Facts NF 56/1-75 "Observing Earth from Skylab"
  - 8) NASA Facts NF 57/1-75 "Why Survey From Space?"
  - 9) Kodak Pamphlet No. M-42 "Photo-interpretation and Its Uses"
  - 10) EROS Data Center, US Geological Survey, Sioux Falls, SD 57198 (Source for Landsat photos of Earth)

### XII. Individual Projects and Demonstrations

- 12-1 Build and launch one or more of the following types of model rockets: Scratch-built, scale, multistage, cluster, payload, boost glider, aerial camera carrier.
- 12-2 Compete in one or more events against other students using similar rocket designs.
- 12-3 Design or use one computer - aided model rocketry activity.

### General Laboratory Related Proficiencies

- G-1 Draw a graph given specific data
- G-2 Interpret graphs
- G-3 Organize and present data in the most appropriate form (i.e. tables, graphs, charts, etc.)
- G-4 Perform correct measurements using both metric and English instruments.
- G-5 Use a computer with pre-programmed routines to enter your own data and obtain meaningful output.

List of Units for Model Rocketry and Aerospace Science (full year course) and approximate time to spend on each.

|                                             | <u>Weeks</u>  |
|---------------------------------------------|---------------|
| I. Constructing and Launching Model Rockets | 3             |
| II. The Laws of Motion and Energy           | 3             |
| III. Rocket Aerodynamics and Propulsion     | 2             |
| IV. Recovery Techniques                     | $\frac{1}{2}$ |
| V. Altitude Tracking                        | $\frac{1}{2}$ |
| VI. The Earth and Solar System              | 2             |
| VII. History of Space Flight                | 7             |
| VIII. Future Space Projects                 | 2             |
| IX. Aerospace Industry and Careers          | 1             |
| X. Group Projects and Reports               | 5             |
| XI. Advanced Model Rocket Techniques        | 4             |
| XII. Individual Projects and Demonstrations | 5             |

This schedule allows most launches and other outdoor activities to be accomplished in Spring and Fall. The course could be made semester length by shortening Units II, VII, VIII, XI and eliminating one major project.

#### Equipment and Supplies

- 1 Phantom plastic see-through rocket
- 2 Launch pads
- 2 Electrical launch control systems
- 2 AltiTraks or astrolabes
- 1 Dynamics cart
- 1 Electrical tick timer, paper tape, and carbon paper disks
- 1 roll of masking tape
- 1 Fin Alignment Guide
- 1 Predicted Altitude Computer
- 6 Earth satellite photos of home state and town
- 1 Assortment of model rocket parts
- 1 Set color slides of spacecraft
- 1 Set color filmstrips on the sun and planets

Students will need the following materials: Model rocket kits, model rocket engines, igniters, wadding, Elmer's glue, single-edge razor blade or model knife, sandpaper.

NAR/HIA\* Model Rocketry Safety Code  
\*National Association of Rocketry  
Hobby Industry of America

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## APPENDIX A

### NAR/HIA MODEL ROCKETRY CODE

1. Construction - My model rockets will be made of lightweight materials such as paper, wood, plastic and rubber, without any metal as structural parts.
2. Engines - I will use only pre-loaded factory made NAR safety-certified model rocket engines in the manner recommended by the manufacturer. I will not change in any way nor attempt to reload these engines.
3. Recovery - I will always use a recovery system in my rockets that will return them safely to the ground so that they may be flown again.
4. Weight Limits - My model rocket will weigh no more than 453 grams (16 oz) at lift-off and the engine will contain no more than 113 grams (4 oz.) of propellant.
5. Stability - I will check the stability of my model rockets before their first flight, except when launching models of already proven stability.
6. Launching System - The system I use to launch my model rockets must be remotely controlled and electrically operated and will contain a switch that will return to "off" when released. I will remain at least 15 feet from any rocket that is being launched.
7. Launch Safety - I will not let anyone approach a model rocket on a launcher until I have made sure that either the safety interlock key has been removed or the battery has been disconnected from my launcher.
8. Flying Conditions - I will not launch my model rockets in high winds, near buildings, power lines, tall trees, low flying aircraft, or under any conditions which might be dangerous to people or property.
9. Launch Area - My model rockets will always be launched from a cleared area free of any easy to burn materials, and I will only use flame resistant recovery wadding in my rockets.
10. Jet Deflector - My launcher will have a jet deflector device to prevent the engine exhaust from hitting the ground directly.
11. Launch Rod - To prevent accidental eye injury I will always place the launcher so the end of the rod is above eye level or cap the end of the rod with my hand when approaching it. I will never place my head or body over the launching rod. When my launcher is not in use I will always store it so that the launch rod is not in an upright position.
12. Power Lines - I will never attempt to recover my rocket from power lines or other dangerous places.

13. Launch Targets & Angle - I will not launch rockets so their flight path will carry them against targets on the ground, and will never use an explosive warhead nor a payload that is intended to be flammable. My launching device will always be pointed within 30 degrees of vertical.
14. Pre-Launch Test - When conducting research activities with unproven designs or methods, I will, when possible, determine their reliability through pre-launch tests. I will conduct launching of unproven designs in complete isolation from persons not participating in the actual launching